

Diesel Engine Major Monitors

- Fuel System
- Misfire
- EGR System
- Boost Pressure Control System



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Fuel System Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
 - fuel system pressure control
 - fuel injection quantity
 - fuel injection timing
- Additional requirement: Detect fault if closed loop system:
 - Fails to enter closed loop
 - Defaults out of closed loop
 - Control authority reaches limits



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Fuel System Monitoring Approach

- Fuel Pressure Control
 - Compare target and actual pressure using pressure sensor
- Fuel Injection Quantity
 - Calculate crankshaft speed fluctuations caused by pilot injection during overrun conditions or other cylinder balance type strategy
- Fuel Injection Timing
 - Compare measured crank angle where fluctuation above occurs with command or use injector inductive signature/"flyback" signal



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Misfire Monitoring

- Requirement for 2010-2012 MY:
 - Must detect misfire occurring continuously in one or more cylinders during idle
- Requirement for 2013+ MY:
 - Monitor for misfire that causes emissions to exceed 1.5 x standards
 - Monitor during entire speed and load range



Misfire Monitoring (cont'd)

- Full-range, intermittent misfire monitoring necessary
 - Aggressive use of EGR and other concepts such as HCCI cause engine to operate near combustion limits at various speeds and loads
- Misfire Monitoring Approach
 - Measure crankshaft speed fluctuation with crankshaft speed sensor



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EGR System Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
 - EGR Flow Rate
 - EGR Response Rate
 - EGR Cooling System Performance
- Additional requirement: Detect fault if closed loop EGR system:
 - Fails to enter closed loop
 - Defaults out of closed loop
 - Control authority reaches limits



EGR System Monitoring Approach

- Flow Rate and Response Rate
 - Compare target and actual flow rate using MAF sensor
 - Measure time to reach target flow rate using same sensor
- EGR Cooling System
 - Monitor cooling effectiveness using EGR temperature sensor(s) or IMT sensor(s)



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Boost Pressure Control Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
 - Under and over boost malfunctions
 - Slow response (VGT systems only)
 - Charge air undercooling
- Additional requirement: Detect fault if closed loop system:
 - Fails to enter closed loop
 - Defaults out of closed loop
 - Control authority reaches limits



Boost Pressure Control Monitoring Approach

- Under and over boost malfunctions
 - Compare target and actual boost pressure using boost pressure sensor
- Slow response (VGT systems only)
 - Measure time to reach target boost pressure using boost pressure sensor and/or turbine speed sensor
- Charge air undercooling
 - Monitor cooling effectiveness using IMT sensor(s)



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Diesel Engine Aftertreatment Monitors

- NMHC Catalyst
- NOx Catalyst (Lean NOx and SCR)
- NOx Adsorber
- PM Filter



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NMHC Catalyst Monitoring

- Requirement for 2010-2012 MY:
 - Detect conversion efficiency fault before NMHC emissions exceed 2.0 x standards
 - Functional monitor to detect fault if:
 - Insufficient exotherm to achieve PM filter regen
 - Insufficient NO₂ feedgas generation for SCR
 - No NMHC conversion on clean-up/guard catalysts
- Requirement for 2013+ MY:
 - Same as above except detect fault before NMHC emissions exceed 1.5 x standards



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NMHC Catalyst Monitoring Approach

- NMHC emission conversion
 - Exhaust temperature sensors to correlate exotherm to conversion efficiency during intrusive post-combustion fueling event
- Functional monitors
 - Exhaust temp sensor for sufficient exotherm for PM filter regeneration and NMHC conversion on clean-up catalysts
 - NOx sensor for insufficient NO₂ feedgas for SCR



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NO_x Catalyst Monitoring

(Lean NO_x and SCR)

- Requirement for 2010-2012 MY:
 - Detect following faults before NO_x emissions exceed the standards by 0.3 g/bhp-hr:
 - NO_x conversion efficiency
 - SCR reductant delivery
- Requirement for 2013+ MY:
 - Same as above except detect faults before NO_x emissions exceed the standards by 0.2 g/bhp-hr



NO_x Catalyst Monitoring (Lean NO_x and SCR) (cont'd)

- Additional requirements for 2010+ MY: Detect a fault if:
 - Separate reductant tank empty or filled with non-reductant
 - Feedback control of reductant:
 - Fails to enter closed loop
 - Defaults out of closed loop
 - Control authority at limits



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NOx Catalyst Monitoring Approach

- NOx emission conversion
 - NOx sensor(s) for higher conversion efficiency systems
 - Exhaust temperature sensor(s) for low conversion efficiency systems (functional type check)
- Reductant delivery/injection
 - Confirm delivery/metering of reductant with NOx sensor (or possibly temperature sensor for open loop/low-efficiency systems)



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NOx Catalyst Monitoring Approach (cont)

- Reductant tank/quality
 - NOx sensor to identify empty tank or non-reductant
 - Alternate approach: tank level sensor and reductant quality sensor (in tank or in exhaust)
- Feedback control
 - Control limits of reductant injection system are reached



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NO_x Adsorber Monitoring

- Requirement for 2010-2012 MY:
 - Detect NO_x adsorber capability fault before NO_x emissions exceed the standards by 0.3 g/bhp-hr
- Requirement for 2013+ MY:
 - Same as above except detect faults before NO_x emissions exceed the standards by 0.2 g/bhp-hr



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NO_x Adsorber Monitoring (cont'd)

- Additional requirements for 2010+ MY: Detect a fault if:
 - Insufficient active/intrusive injection to achieve desorption of NO_x adsorber
 - Feedback control of NO_x adsorber or active/intrusive injection system:
 - Fails to enter closed loop
 - Defaults out of closed loop
 - Control authority reaches limits



NO_x Adsorber Monitoring Approach

- NO_x adsorber capability performance
 - A/F sensors before and after to correlate desorption time with performance
 - NO_x sensors could also be used
- Active/intrusive injection
 - A/F sensors before and after to verify rich exhaust condition achieved
 - NO_x sensor(s) could also be used



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PM Filter Monitoring

- Requirement for 2010-2012 MY:
 - Require following faults to be detected before PM emissions exceed 0.05 g/bhp-hr:
 - Filtering Performance
 - Infrequent Regeneration
- Requirement for 2013+ MY:
 - Same as above except detect fault before PM emissions exceed 0.025 g/bhp-hr



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PM Filter Monitoring (cont'd)

- Additional requirements for 2010+ MY:
 - Detect: (before NMHC emissions exceed 2.0x std)
 - too frequent regeneration
 - catalyzed filter NMHC conversion efficiency
 - Functional monitor for:
 - Incomplete regeneration
 - Missing substrate
 - Insufficient injection for active PM filter regeneration
 - Detect a closed loop regeneration system fault:
 - Fails to enter closed loop
 - Defaults out of closed loop
 - Control authority reaches limits



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PM Filter Monitoring Approach

- Filtering Performance
 - Differential pressure sensor, inlet temperature sensors, and PM loading model to correlate to filtering performance
- Infrequent Regeneration
 - Comparison of regeneration triggers (differential pressure sensor, PM loading model, time/distance) to identify improper PM loading



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PM Filter Monitoring Approach

- Catalyzed NMHC Conversion
 - Temperature sensors to measure performance during active regeneration
- Too Frequent/Incomplete Regeneration
 - Comparison of regeneration triggers (differential pressure sensor, PM loading model, time/distance) to identify improper PM loading
- Missing Substrate
 - Differential pressure sensor and exhaust flow rate to identify unacceptably low backpressure



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Diesel Engine Additional Monitors

- Exhaust Gas Sensors



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Exhaust Gas Sensor Monitoring

- A/F sensors:
 - For upstream sensors,
 - Detect fault before any emissions exceed 1.5 x standards
 - For downstream sensors in 2010-2012:
 - Detect fault before aftertreatment thresholds exceeded (NMHC 1.5 x standard, NOx standard plus 0.3 g/bhp-hr, or PM 0.05 g/bhp-hr)
 - For downstream sensors in 2013+
 - Same as above but with final aftertreatment thresholds (NMHC 1.5 x standard, NOx standard plus 0.2 g/bhp-hr, or PM 0.025 g/bhp-hr)



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Exhaust Gas Sensor Monitoring (cont'd)

- NOx sensors:
 - 2010-2012 MY: Detect fault before aftertreatment thresholds exceeded
 - NMHC 1.5 x standard, NOx standard plus 0.3 g/bhp-hr, or PM 0.05 g/bhp-hr
 - 2013+ MY: Same as above except detect fault before final aftertreatment thresholds
 - NMHC 1.5 x standard, NOx standard plus 0.2 g/bhp-hr, or PM 0.025 g/bhp-hr



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Exhaust Gas Sensor Monitoring (cont'd)

- Additional requirements for 2010+ MY: Detect the following faults for all sensors:
 - Circuit/out-of-range faults
 - Feedback faults that cause an emission control system to default out of closed loop
 - Insufficient performance of the sensor for use for other OBD monitors
 - Heater performance and circuit faults



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Exhaust Gas Sensor Monitoring Approach

- Upstream/downstream A/F and NO_x sensors
 - Analyze sensor output and response during known exhaust conditions
 - e.g., overrun, idle, steady cruise, with or without EGR, during active injection for PM filter regeneration or NO_x adsorber desorption



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Gasoline Engine Monitors

- Same as light-duty OBD II monitoring requirements (section 1968.2)
 - Emission thresholds tied to 1.5 or 1.75 x standards for major monitors
 - Evap leak check for 0.030” instead of 0.020”
 - Phase-in of 0.090” for 2010-2012
 - Final size of 0.030” for 2013+



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Gasoline Engine Monitors (cont'd)

- Alternate-fueled engines
 - Subject to requirements for gasoline engines (even if they are derived from a diesel engine)
 - 2010-2016MY: May request relief/exemption from monitoring requirements
 - For any monitor where monitoring may be unreliable with respect to the alternate fuel



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Diesel and Gasoline Engine Monitors

- VVT System
- Cooling System
- PCV System
- Comprehensive Components
- Other Emission Systems



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VVT System Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
 - target error
 - slow response
- Monitoring Approach:
 - Compare target (commanded) and actual (sensed) valve timing and/or lift



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Cooling System Monitoring

- Requirement: Monitor cooling system (e.g., thermostat, ECT sensor) for proper performance:
 - must reach minimum temperature necessary to enable other OBD monitors or any emission control strategy within a reasonable time
 - must reach near thermostat-regulating temperature within a reasonable time



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Cooling System Monitoring (cont'd)

- Will likely require engine manufacturers to set upper and lower bounds on amount of heat that coach builders may take out of system during warm-up
 - e.g., max heat removed from the engine side of the thermostat during warm-up
- Monitoring approach:
 - Compare actual temperature with warm-up model (based on start-up temp, ambient, driving conditions, etc.)



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PCV System Monitoring

- Gasoline requirement: Detect disconnection of the system between:
 - the crankcase and PCV valve, or
 - the PCV valve and the intake manifold.
 - Or, design the systems to avoid disconnection
- Diesel requirement: Submit plan for review:
 - Combination of detection and, more likely, design of the system to avoid disconnection



Comprehensive Component Monitoring

- Required to monitor electronic components that are used/inputs to the engine controller and that:
 - can cause a measurable emissions increase during any reasonable driving condition, OR
 - affect any other OBD monitors
- Requirement: Detect following faults:
 - circuit and rationality faults for input components
 - functional faults for output components
- Monitors not tied to emission thresholds



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Comprehensive Component Monitoring (cont'd)

- Components “outside” of the engine
 - Required to monitor: Transmission/other powertrain components used by the engine controller for enabling, disabling, or malfunction determination (e.g., VSS or park/neutral switch used to disable monitors)



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Comprehensive Component Monitoring (cont'd)

- Components “outside” of the engine
 - Not required to monitor: transmission components that aren’t used by the engine controller (even if they could fail and cause the trans to operate in a manner that won’t run one of the engine monitors)
 - e.g., shift solenoid that results in the engine not shifting to all gears and that results in reduced engine speed range



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Other Emission Control System Monitoring

- Required to monitor other emission control systems that are:
 - not identified under the other monitoring sections, OR
 - identified as a comprehensive component, but not corrected or compensated for by an adaptive control system
- Manufacturers required to submit a plan detailing monitoring strategy and malfunction criteria for ARB approval



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